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A GEOGRAPHICAL OVERVIEW OF THE SOILS OF ZIMBABWE AND THEIR AGRICULTURAL POTENTIAL

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INTRODUCTION

Zimbabwe is endowed with a wide range of soils. The soils vary considerably in their age and degree of development, physical, chemical and mineralogical composition and, therefore, also in their landuse potential. To a very large extent, their distribution is closely related to the nature and distribution of geological materials. Spatial variations that occur within a given area of parent material are then the result of the influence of the other soil-forming factors, especially climate and topography. In order to fully appreciate the variations in the distribution of soils, it is generally useful to examine the factors that have contributed to the development of the soils and then review the soil patterns in that context. In the sections that follow, such an approach will be adopted.

THE INFLUENCE OF SOIL-FORMING FACTORS

Historically, pedologists have used 5 soil-forming factors as the paradigm for soil genesis. While the early view was to consider each of them as an independent variable, the view that has the most endorsement and currency is one which views these factors as interdependent with the clear acknowledgement that, in some cases, one factor may be more dominant than the others to the extent that soil formation is influenced by it more than by the others in a given locality and at a given time. In Zimbabwe, as pointed out already, the parent material factor is generally the most dominant. However, the influences of climate and topography impart many of the most important characteristics that differentiate some of the major soil types from each other. Each of these factors, as well as other soil-forming factors, will now be examined in turn.

Parent Material

Table 1 is a summary of the major classification of rocks. This should assist in understanding and appreciating the terms used to describe differences between parent materials. In particular, it should be noted that the term 'acid' refers to rocks with a dominance of silica over other materials and is thus not the same as the concept based on pH measurement, although acid rocks also tend to give rise to soils that have an acidic pH.

Table 1: Classification of Rocks

Type	% Ferromagnesian Minerals	% Silica (SiO_2)
1. Ultrabasic (Ultramafic)	>90	0 – 45
2. Basic (Mafic)	60 – 90	45 – 55
3. Intermediate	20 – 40	55 – 65
4. Acid	5 – 20	65 – 85
5. Extremely Acid	<5	>85

An examination of the national 1:1 000 000 geological map and the soil map of the same scale will show a very high degree of correspondence between the boundaries of geological mapping units and soil boundaries. Over 66% of the area of this country is covered by crystalline rocks, of which granites are by far the most predominant. As a result, soils of granitic origin cover 46% of Zimbabwe (Purves, 1976).

The various parent materials give the soils their characteristic physical, chemical and mineralogical properties. These may, of course, be altered further by various environmental conditions. The amount and type of clay and the amount and proportion of the various sand fractions are largely a direct product of the mineralogical and crystal composition of the parent rock. In the first instance, the type of clay is mainly a function of the proportion of primary minerals, especially the ferro-magnesian minerals, in relation to the other major constituents of rocks. In due course, the fate of the primary minerals will depend very much on the environmental conditions under which these primary minerals finally undergo weathering. Table 2 shows the general range of clay contents and the typical distribution of sand size particles for selected parent materials that are common in Zimbabwe.

Table 2: Relationship between parent material and soil particle size[1] distribution

Parent Material	Sand			Silt	Clay
	fine 0.1-0.25 mm	medium 0.25-0.5 mm	coarse 0.5-2.0 mm	0.02-0.002 mm	<0.002 mm
Kalahari	68	18	5	3	6
Basalt*	9	3	1	15	68
Mafic gneiss	13	18	11	14	44
Gabbro*	9	6	5	17	60
Argillaceous sediment*	27	10	1	20	37
Granite*	26	28	27	8	9

Source: Nyamapfene, 1991.
* Balance to 100% is gravel
1 Particle size ranges are based on USDA nomenclature

It can be seen that the mafic parent materials generally give rise to soils in which clay content is relatively high. The more sandy soils, on the other hand, owe their sandy nature to the siliceous composition of their parent rocks, which are dominated by quartz and have relatively low quantities of weatherable minerals.

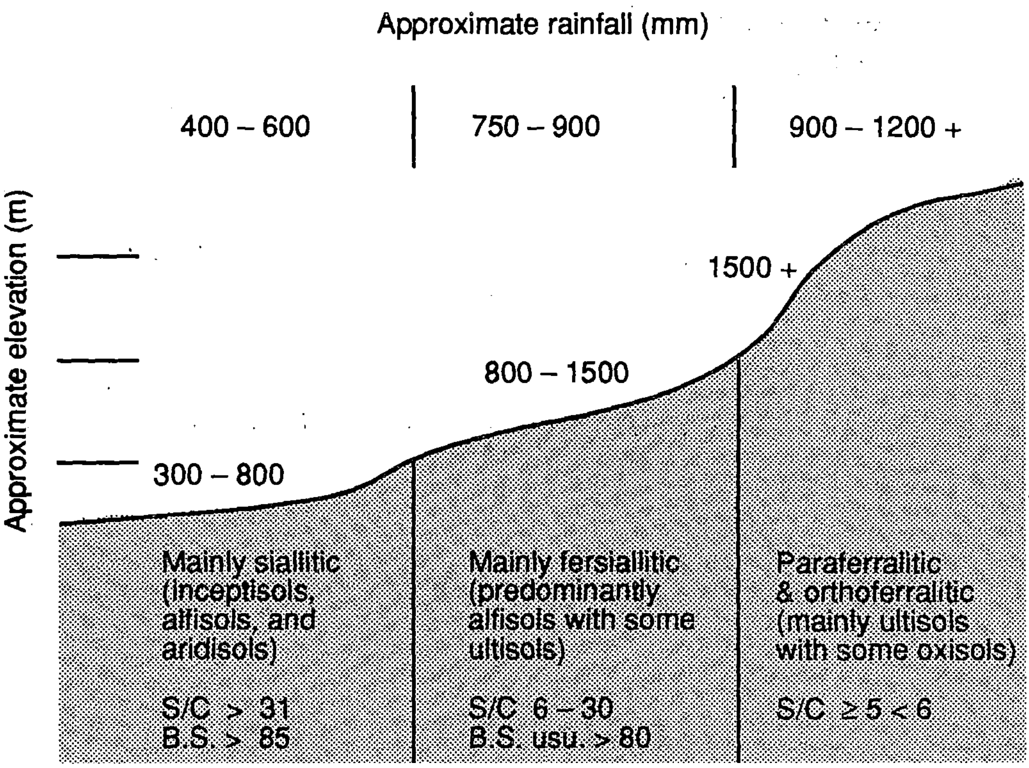
Climate

After parent material, the next most profound influence on soil development is climate and, in particular, the rainfall aspect of climate. In Zimbabwe, mean annual rainfall generally increases from south to north and from west to east. The temperature gradient also tends to follow a west-east trend with temperatures getting lower as one moves from the Lowveld through the Highveld to the Eastern Highlands. As a result, most of the soils to the north, west and south of the 800 mm isohyet are relatively young and unleached and are therefore very high in bases. Except where the soils are of alluvial origin, soil depth is often less than 1 metre. Horizon differentiation may be weakly to moderately expressed except in some soils derived from granites and gneisses where major differences in clay content with depth are often manifested as differences in colour and/or structure.

In contrast, the soils of the wetter Highveld and Eastern Highlands, particularly those derived from mafic rocks, tend to be deeper and more brightly coloured. The red soils found in the Eastern Highlands and over much of the Central Watershed are older and relatively more leached with the bright colours being a reflection of the higher levels of iron oxide remaining in the soil system. Bases and other constituents of the primary minerals are lost through weathering and leaching. Iron, manganese and aluminium which are resistant to weathering are therefore important constituents of these soils while they are found in somewhat smaller quantities in the younger base-rich soils of the south, south-west and south-east as well as the Zambezi Valley.

Figure 1 gives a generalised overview of how soils on a given mafic parent material would change as rainfall increased. Clearly, therefore, climate has a great deal of influence on the development and distribution of soils in Zimbabwe.

Figure 1: Schematic representation of the relationship between rainfall and soils



Topography

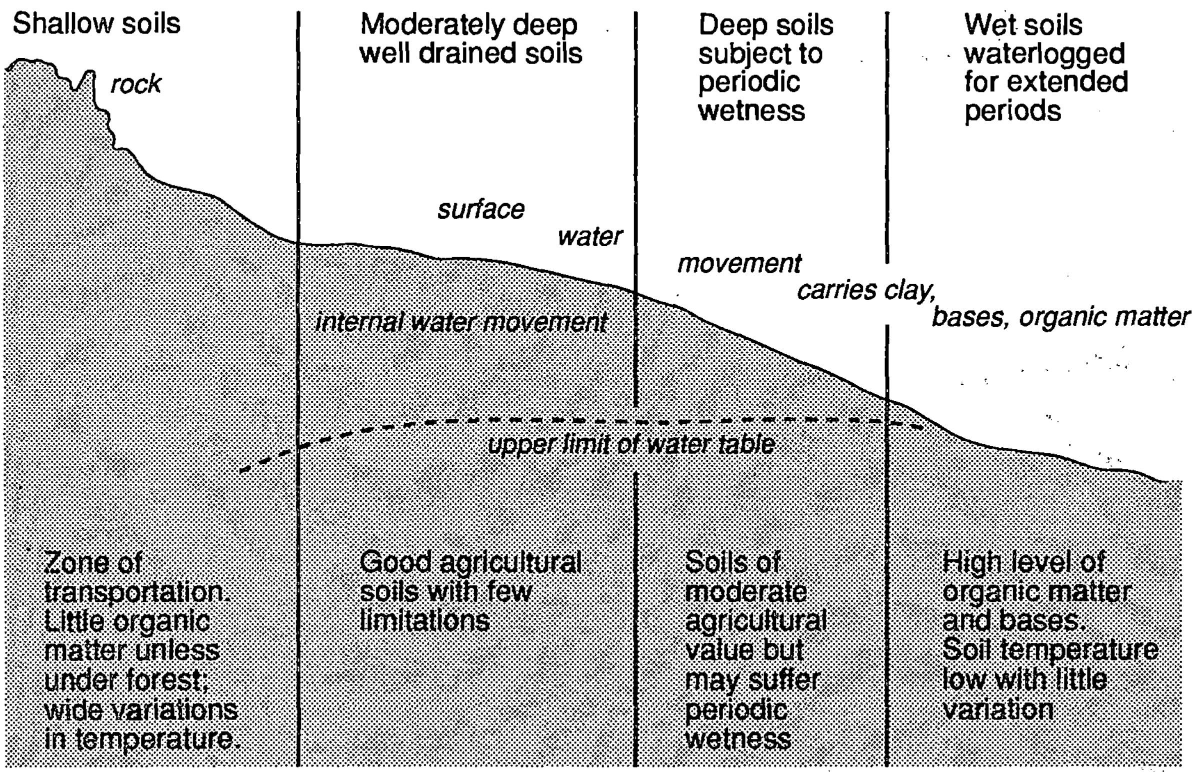
The role of topography in soil formation and development is often thought to be minor and is generally poorly conceived or understood. Before going into any detailed discussion on the influence of this factor in the Zimbabwean context, it is necessary to clarify, in general terms, how the influence of topography is manifested.

One of the most important effects of topography is that it redistributes the energy from the climatic elements, especially rainwater and temperature. It is common knowledge that, after a few weeks of rain, the uplands may be moist but remain freely draining while in the **vleis** and **vlei** margins, the soil becomes very wet and waterlogged. This immediately causes differences in the rate at which chemical and microbial weathering reactions take place and so, eventually, results in differences in soil properties. With regard to heat energy, we know that north-facing slopes, (in the southern hemisphere) receive a higher total of solar radiation than those with a southern aspect. Aspect therefore becomes important where there is a slope variation in topography and, in turn, topography by thus reducing solar energy causes differences in temperature which affect the rate of biological and chemical reactions. Even physical processes, such as the rate of evaporation of water from the soil, are affected by temperature and, in the final analysis, cause differences in the nature of soils.

In Zimbabwe, the influence of topography is so important that it is used to differentiate soils at the series level by use of the catena. A catena is defined as a repetitive sequence of soils along a slope. The seasonality of rainfall over most of Zimbabwe makes the expression of these catenal variations stronger than would otherwise be the case. For example, during the dry winter months, the soils in the upper parts of a slope become quite dry and thus soil-forming processes are almost at a standstill, except for oxidation. In the lowest slope positions, on the other hand, the continuing abundance of moisture restricts oxidation processes and facilitates reduction of oxides. As the water table rises and recedes in these **vlei** areas, alternating reduction and oxidation occurs, respectively, which results in the development of a mottled pattern of brightly coloured patches of red, orange or yellow in a matrix which itself is often a greyish brown colour. Therefore, an easy way of assessing the suitability of a given soil for crops which, to use a popular expression 'cannot stand wet feet', is to see if the subsoil is mottled.

Figure 2 is a schematic representation of the way in which topography can influence soils types and soil conditions, on a catena. Because of differences in topography, there will be differences in the distribution of soil constituents as shown below. The upland areas become a ZONE OF LOSSES while the lower slope areas become a ZONE OF ACCUMULATION.

Figure 2: Schematic representation of the influence of topography



The Biotic Factor

The influence of all forms of life, including man, on soil formation is to be found to varying degrees in different parts of Zimbabwe. In the very earliest stages of weathering, namely the initial disintegration of rock, one biotic form that has been found to be extremely important and widespread is lichens. These are found in such diverse climatic environments as hot deserts, the tropics and even the Arctic region. Unless one is consciously looking out for them, it is easy to miss them altogether and discount their role. This is because their growth habit makes them appear to be part of the rock surface which they cover. In Zimbabwe, lichens grow most abundantly on granitic rocks and tend to proliferate in the wetter parts of the country. In fact vigorous growth can be observed almost everywhere and is especially evident where the mean annual rainfall exceeds 550 mm, with some of the most spectacular cases being found in the Eastern Highlands. Evidence of their contribution in the disintegration of the rock may not always be obvious but close examination of rock surfaces often shows large pock marks in places where the litter of senescent lichens is present. Admittedly, their overall contribution only becomes significant over millenia.

Probably the most extensive, readily observable and significant biotic contributor to soil formation in Zimbabwe is the termite, although largely only from the stage when there is already partially weathered saprolite and also in changing the form and contents of soil already formed. Termites are known to move thousands of tons of soil every year. The overall effect of this is that they bring up materials from the sub-soil to somewhere near the surface where weathering of any primary minerals present proceeds more rapidly, resulting in the release of bases such as calcium and potassium. As a result, termite mound soils have been found to have a higher base content than surrounding soils. They also tend to be more clayey, which increases their waterholding capacity. These two properties of termite mound soils make them ideal as an amendment for low fertility sandy soils which have a low water holding capacity. Nyamapfene (1986) discusses some of the uses of such soils as amendments for low fertility soils. Watson (1969,1974, 1975, 1976) studied the variations in the properties of termite mound soils in different parts of the country and the data for some of these are summarised in Table 3.

Table 3: Selected Properties of Termite Mounds and Adjacent Soils

Site	Depth cm	Coarse Sand 2.0–0.2 mm	Sand 0.2–0.02 mm	Silt 0.02–0.002 mm	Clay <0.002 mm	pH*	Cond‡ mhos/ mm	% Calcium carbonate ($CaCO_3$)	Organic Carbon
Melfort	0 – 45	24	33	20	23	5.7	40	–	1.92
Mound	45 – 165	19	17	17	29	5.3	45	–	1.22
	165 – 255	16	18	18	35	5.0	42	–	0.82
Melfort	0 – 30	59	24	8	9	4.4	27	–	0.88
Adjacent	30 – 35	60	24	7	9	4.8	27	–	0.30
Soils	75 – 135	68	21	5	6	5.4	30	–	0.19
	135 >	53	26	7	14	5.4	48	–	0.10
Kutsaga	0 – 38	30	38	15	17	7.2	200	0.50	0.81
Mound	38 – 117	24	40	16	20	6.6	900	0.33	1.95
	117 – 175	27	35	16	22	7.4	210	6.07	0.80
Kutsaga	0 – 10	67	23	5	5	4.9	60	–	0.88
Adjacent	10 – 43	57	31	7	5	4.6	50	–	0.14
Soil	43 – 150	66	24	4	6	4.7	55	–	0.06

Source: Watson (1969)

* pH is 1:5 calcium chloride ($CaCl_2$)

‡ conductibility was measured on a 1:5 soil : water suspension

In Zimbabwe, the impact of vegetation on soils becomes difficult to describe because of the disturbance to vegetation which has taken place in most of the country. Therefore, although some very important soil-vegetation relationships exist (Nyamapfene, 1988), it is difficult to assess the role of vegetation as a soil-forming factor.

Time

About one third of Zimbabwe lies on relatively young geological formations. These include the extensive area of Kalahari sand, Karoo sandstones and other sediments as well as the less extensive but notable sedimentary formations often associated with the Gold Belt formation of the Basement Complex and the alluvia of the larger rivers especially the Save and its tributaries. All these formations give rise to soils in which profile development is at a minimum. They are therefore very young soils. Over the larger area taken up by the much older Basement Complex, not all the soils are old. In fact, because of the generally steep slopes over much of the area, a great deal of natural erosion takes place, thus keeping in check the rate of soil formation. Lithosols and other younger soils occur widely in these areas.

It is only on the geologically old and geomorphologically stable parts of the Central Watershed and the plateau areas of the Eastern Highlands that old soils are to be found. These include the highly leached, yellowish brown paraferrallitic soils derived from granites which are found in the area from Marondera through Wedza in the south and Headlands in the north to Rusape. Then there are also the bright red, orthoferrallitic clays found in most of the Eastern Highlands. Both these groups of old soils are characterised by their deep profiles, often in excess of three metres, and a highly weathered mineral fraction.

SOIL CLASSIFICATION IN ZIMBABWE

The system of classification used in Zimbabwe was developed by Thompson (1965). The history of the classification and the rationale are documented in detail in Thompson and Purves (1981) and Nyamapfene (1991). A full discussion of the classification is somewhat beyond the scope of this paper. However, to facilitate an understanding of the soils in the context of this paper, an outline of the classification is given in Table 4 with a brief summary of the properties of the soils in each of the main categories.

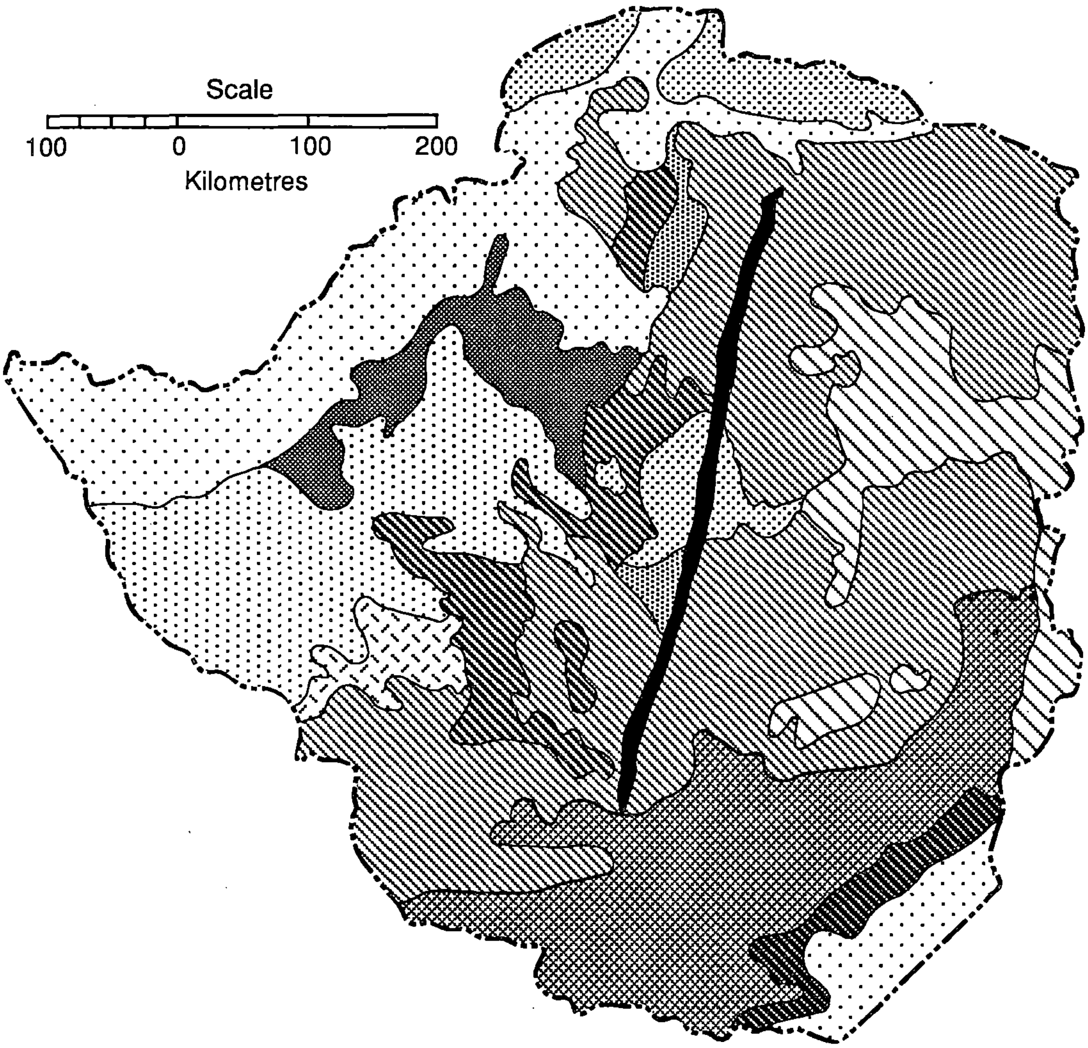
Table 4 does not show the relationships at Family and Series levels which come immediately below the Group level. It would be necessary to go into a somewhat detailed explanation as to how one arrives at each of these levels, which is really beyond the scope of this paper. The reader is therefore referred to Thompson and Purves (1981) and Nyamapfene (1991). More important for use in the field, however, is an understanding of the potential use that can be made of the soils in the eight main Groups and their constraints to production. Table 5 is a summary of such information, while Figure 3 shows the general distribution of the major soil groups.

Table 4: Simplified Outline of the Soil Classification System of Zimbabwe

Order	Group
I Amorphic Soils with very feeble development of genetic horizons.	**1. Regosol** Deep sands **2. Lithosol** Extremely shallow soils
II Calcimorphic Unleached soils, generally with large reserves of weatherable materials: high base saturation, clay fractions predominantly active.	**3. Vertisol** Very active clay **4. Siallitic** Active clay
III Kaolinitic Moderately to strongly leached soils; clay fractions mainly inert together with appreciable amounts of free sequi-oxides of iron and aluminium.	**5. Fersiallitic** Mixed clay **6. Paraferrallitic** Inert Clay **7. Orthoferrallitic** Very inert clay
IV Natric Soils which have presence of significant amount of exchangeable sodium in the upper part of the profile.	**8. Sodic**

Source: Purves, *et al.*, 1981

Figure 3: Generalised distribution of the main soils of Zimbabwe



1. Predominantly shallow soils of very little agricultural value. (Lithosols)
2. Deep sands of no agricultural value, but sometimes support stands of fine indigenous timber. (Regosols)
3. Predominantly hard impermeable soils with high content of salts. (Sodic Soils)
4. Yellow to yellowish grey soils, high in silt, poor structure, highly erodible, low agricultural value. (Siallitic and Fersiallitic, mainly)
5. Deep to moderately shallow soils, derived from alluvium and sediments. (Mainly Siallitic)
6. Deep to moderately deep, well drained, red to reddish brown soils of high agricultural value. (Mainly Fersiallitic)
7. Yellowish and yellowish brown to brown sandy loams and sandy clay loams of good agricultural value. (Mainly Fersiallitic)
8. Red and yellowish brown soils of high rainfall areas. Deep and highly leached sandy clay loams and clays which are usually acid and low in fertility. (Paraferrallitic and Orthoferrallitic)
9. Black clays and sandy clays of varying depths. Good for irrigated wheat, cotton and other crops. (Vertisols)
10. Mixture of 6, 7, and 2.
11. Mixture of 1 and 4.

Great Dyke with pockets of deep, red and brown soils.

Table 5: Relationship Between Soil Groups and the Use Potential of Soils

Soil Group	Major distinguishing factors	Use potential/constraint
Regosol	Deep sand profile with little horizon development except for slightly organic-rich A horizon. Combined clay and silt <10%. May be several metres deep. Very low nutrient reserves.	Main limitation is low water holding capacity due to low clay content. Soils with mainly fine sand may hold water for slightly extended periods especially where there is little slope.
Lithosol	Shallow soils not more than 25 cm deep. Clay content and nutrient levels largely dependent on parent material type. Where soil is not sandy, clay is often of the active type. Nutrient levels can be quite high due to limited weathering.	Shallowness limits potential for commercial crop production. Shallow rooting crops may be grown under rainfed conditions at subsistence level, taking advantage of the relatively high natural nutrient levels especially potassium and calcium from weathering feldspars.
Vertisol	Heavy, cracking clay, usually black or dark grey. High content of clay (usually >40%) of the very active, very sticky type. Very high levels of bases especially calcium and magnesium. Extensive cracks, usually evident on the surface of the soils when soil is dry. Have a high shrink-swell coefficient. Shrinking when dry causes stress resulting in extensive cracking.	Generally good for crop production but require much water. Generally no fertility problems though micronutrients e.g. zinc and molybdenum may be deficient for some crops. Shrink-swell property makes these soils unsuitable for use as an engineering bed for road building or for laying of building foundations. Very sticky and slippery when wet, making use of machinery difficult.
Siallitic	Usually have a relatively high clay content and are rich in bases. Although some may crack, this is not as extensive as in vertisols because the amount of very high activity clays is somewhat less.	Where soil structure and drainage are not limiting, these soils offer almost unlimited potential for agricultural use. Where clay content and type approach those of vertisols, similar engineering problems to those described above may arise.
Fersiallitic	Have a moderate amount of active clay and bases but are distinguished from the siallitic by presence of less active clays, mainly kaolinite, and some oxides. Colours depend mainly on parent material and drainage conditions. Those derived from the very extensive and almost ubiquitous granite tend to be yellow to yellowish brown in well-drained positions. Where the granite is rich in iron minerals, they may become yellowish red to reddish brown. Red and reddish browns are the common colours where the parent material is mafic.	Because of their moderate range of most properties, they make very good agricultural soils, but require certain management inputs depending on the nature of the limiting factor and crop type. The presence of a moderate amount of oxides results in a fairly porous soil medium which drains readily and thus makes them good for both rainfed and irrigated agriculture. It also makes them fairly resistant to erosion.

Paraferrallitic	More leached than fersiallitic and have oxides, only a small amount of active clays and weatherable minerals left in the system. Clay content depends on parent material, being moderate to high in most cases. Clay fraction is less sticky i.e. evidence of being more inert and fails to develop 'body' when clay is kneaded. Mostly derived from granite and have substantial amounts of coarse sand. Colours commonly yellowish-brown to yellowish-red.	Can be used for a wide range of agricultural activities. However, require some amendments including lime, in some cases. Since they tend to occur on sloping lands and plateaux, conservation measures are often necessary. Those derived from true granites are typical 'tobacco sand-veld' soils which are good for production of that crop as well as groundnuts, potatoes, pastures etc.
Orthoferrallitic	Very highly leached. Less than 5% weatherable minerals. Clay fraction is very inert, being predominantly made up of kaolinite and related low activity clays as well as oxidic clay materials such as haematite, gibbsite, goethite etc. Moderate to high clay content but clay lacks stickiness. Usually very deep, porous profiles which drain freely. Common colours are red and bright red, except for a few occurrences associated with low clay-yielding parent materials in which case yellowish red colours are more likely. Acidic in reaction and low in fertility.	Although low in fertility, their depth and porous structure make them suitable for the production of a wide range of tree crops. Where appropriate management practices can be adopted, other crops can also be grown. Their occurrence mainly in the cool, high rainfall parts of the country, makes for a very wide range of possibilities.
Sodic	As the name implies, very high sodium content. pH values are mainly in the neutral to alkaline range although, as the soils become leached, sodium contents may remain high but with pH's falling below neutral into the slightly acid range. Where the high sodium is not accompanied by the high calcium, the soils tend to be very hard and dense. Many are apedal but where structure develops, it tends to be a characteristic columnar structure in the subsoil underlying an otherwise loose apedal surface horizon. Colours are generally pale yellows, yellowish greys and greys.	Only crops tolerant to sodicity and alkalinity may be grown e.g. rice. High density and compactness make for poor water transmission and impede root development. The clay fraction is highly dispersible, thus making the soils very erodible and subject to piping. This also makes them unsuitable for dam or road construction and for other engineering purposes.

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